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CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE, UNDER THE DIRECTION OF E. L. MARK. — No. 129.

CERTAIN SENSE ORGANS OF THE PROBOSCIS OF THE POLYCHAETOUS ANNELID RHYNCHOBOLUS DIBRANCHIATUS.

By Adèle Oppenheimer.

With Six Plates.

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Presented by E. L. Mark, April 13, 1898. Received February 15, 1902.

The proboscis of Rhynchobolus dibranchiatus was described by Ehlers ('64–68, p. 670) as "short, thick, club-shaped, with small egg-shaped papillae (compare Plate 1, Fig. 1), and was divided by him (p. 678) into two parts, the "Rüsselröhre," or sheath of the proboscis, and the "Kieferträger," or bearer of the jaws. Before eversion the "Rüsselröhre" is anterior to the "Kieferträger," but when the proboscis is everted (Fig. 1) the latter is anterior. The "Keiferträger" may be subdivided, as Ehlers suggested, into three regions, which in the non-everted state are respectively anterior, middle, and posterior: (1) the anterior has none of the small egg-shaped papillae; (2) the middle region is that supporting the four jaws; and (3) the posterior is, as a rule, not everted, it is the region of the four glands (*gl.*) of the jaws and the remainder of the proboscis following the glands. The boundary between "Kieferträger" and "Rüsselröhre" is marked, according to Ehlers, by the place of attachment to the proboscis of four partial diaphragms, called by him "Lappen" (Fig. 1, *lmn.*).

When cross sections of the everted proboscis are made in the region of the four partial diaphragms (Fig. 2), one encounters in succession in passing from the surface toward the centre (1) a cuticula (*cta.*); (2) an epithelial layer (*e'th.*); (3) a connective-tissue layer (*tis. co'nt.*), in which are embedded eighteen longitudinal nerves (*n. lg.*), and a nerve plexus; (4) a region composed of eighteen longitudinal muscles (*mu. lg.*); (5) a sheet of circular muscles (*mu. crc.*); (6) a fascia or peritoneum (*pi'tn.*)

lining the body-cavity; then in the body-cavity the four partial diaphragms; and finally that part of the proboscis which has not been everted. This consists of nearly the same kinds of layers arranged in the reverse order, namely a peritoneum, circular muscles, longitudinal muscles, nerves, connective tissue, and cuticula.

The epithelial layer directly beneath the cuticula is not mentioned as such by Ehlers. Since it apparently undergoes an interesting metamorphosis, it is worthy of further study.

From the underlying connective-tissue layer eighteen projections of connective tissue pass radially inward between the eighteen longitudinal muscles to the region of the circular muscles. Where the radial projections are continuous with the outer circular portion of the connective tissue the eighteen longitudinal nerves (*n. lg.*) are seen cut crosswise. (Compare Pl. 2, Fig. 10.)

Concerning the structure of these longitudinal nerves I have nothing to add to what Ehlers ('64–68, p. 696) has already pointed out. They are evidently surrounded by a protecting connective tissue, within which lie what are apparently nerve fibres. In preparations fixed in vom Rath's picric-osmic-platinic chloride-acetic mixture, the nervous plasm is flocculent and has shrunken away from the nerve sheath.

From these longitudinal nerves, fibres pass out (Pl. 2, Fig. 10) to form the peripheral nerve plexus, which is embedded in the connective tissue occupying the space between the longitudinal muscles and the cuticula. Other nerve fibres (*n. r.*) starting from the plexus pass radially inward, skirting the longitudinal muscle (Fig. 10); yet apparently they do not innervate the muscles, for I have seen no nerve fibre pass through the sheath enclosing the muscle. Still other radial nerve fibres (*n. r.'*) can be followed from the longitudinal nerves passing through the middle of the radial connective-tissue projections toward the centre of the sections as far as to the membrane immediately superficial to the circular muscles (Pl. 1, Fig. 2; Pl. 2, Fig. 10). In the anterior region, where the four partial diaphragms, the "Lappen" of Ehlers, are attached to the wall of the proboscis, radial nerve fibres occupying the same relative position as those marked in other regions *n. r.'* can be traced into these four pendent structures. Ehlers says concerning these "Lappen" (p. 686): "By means of a fold it [the fascia which invests the surface of all these parts] forms the four 'Lappen,' which are attached at the boundary between 'Rüsselröhre' and 'Kieferträger;' these 'Lappen' therefore possess the fine tense membrane on both surfaces; between lies a fibrous tissue, which is apparently identical with

the subcuticular tissue of the sheath of the proboscis, with which, moreover, it is evidently continuous. This tissue . . . consists of a fibrous network, in the meshes of which lie ganglion cells." Further on (p. 696) he says: "The ganglion cells between the leaves of these 'Hautlappen' lie in a single layer and are surrounded by strands of fibres, so that they lie as it were in the meshes of such a net made up of bundles of fibres; however, it seems to me very doubtful whether these strands of fibres which make the meshes are all of nervous nature; on the contrary I believe that the greater mass of this fibrous tissue is identical with that which lies under the chitinous cuticula of the 'Rüsselröhre' and forms the sheath of the longitudinal nerves."

If I understand Ehlers correctly (he has no figures showing these histological conditions), I do not entirely agree with him concerning the structure of the "Lappen." Within the peritoneum I find connective tissue, ganglion cells, and also cells not mentioned by Ehlers (Pl. 2, Figs. 7, 8). These last have an epithelial character; they form, indeed, the main bulk of the lobe, as appears both in material prepared in the vom Rath mixture and in two haematoxylin preparations made from material fixed respectively in corrosive sublimate and in sublimate-acetic. The "Fasergewebe" of Ehlers I consider nervous in large part. Almost all of the fibres (Fig. 8) surround, not the ganglion cell, as one might infer from his description, but its nucleus, and pass out at one pole of the cell body to the longitudinal nerves of the proboscis.

Finally, nerve fibres from the longitudinal nerves and from the peripheral nerve plexus can be traced out peripherally into the small papillae which are thickly distributed over the surface of the "Russelröhre."

Through the kindness of Mrs. Margaret Lewis Nickerson, who suggested to me the subject of the present paper, I was able to begin my study of the distribution of the sensory papillae of the proboscis on a preparation of the cuticula already made by her. The cuticula had been prepared by a method which was first employed by Mrs. Nickerson. All my subsequent preparations of the cuticula of other individuals were secured by the same method, which was as follows: The worm, after being narcotized in a mixture of sea-water and alcohol, was placed in a ten per cent solution of common salt until it was evident that its skin was loosened from the body. A cut was then made through the cuticula along a longitudinal line of the body, and the animal placed in tap-water. After the salt had been thoroughly washed out, the worm was cut transversely into pieces short enough for the cuticula to be mounted conveniently on a slide. The cuticula was next peeled off with needles

and floated upon glass slides. These preparations were ready for study as soon as they were dry.

The whole surface of the proboscis, except the part which is most anterior in the usual state of eversion (Fig. 1), is covered with conical or thimble-shaped papillae, which are arranged on the summit of transverse folds (Pl. 5, Figs. 32, 33). In general the axes of the papillae are perpendicular to the surface of the proboscis, or are directed outward and either slightly backward or slightly forward. The rows of papillae are as a rule separated from each other by regular intervals, but sometimes there is an anastomosis (Fig. 32) of the folds from which these organs project. The folds follow one another closely, and there are one or two rows of papillae to each fold. At the posterior part of the everted proboscis the transverse rows are divided into eighteen longitudinal groups (Fig. 33); the interspaces correspond to the position of the eighteen longitudinal nerves. Otherwise the arrangement and frequency of these organs is the same from the anterior to the posterior end of the proboscis, and there is no other evidence of special grouping in any part.

The papillae are more or less ovoid or conical. On a proboscis about $5\frac{1}{2}$ mm. in diameter at the anterior end, they were found to be about 80 μ in height and about 35 μ in diameter at the thickest part.

The cuticula of the proboscis passes over each papilla, but is here reduced to about two-thirds the thickness it has elsewhere. The cuticula of the posterior face of each papilla is coarsely corrugated. The ridges are most clearly seen in preparations of removed cuticula (Pl. 6, Fig. 34), or in sections stained in Kleinenberg's haematoxylin (Pl. 1, Fig. 6; Pl. 3, Fig. 13). Though varying in number in different papillae, the ridges show considerable regularity of form and arrangement, for the outlines produced by them are always rather sharply bent in a region corresponding with the middle of the posterior face of the papillae, so that the surface view of that face shows a series of V-shaped outlines, like the longitudinal section of a nest of funnels, the apices of the V's being directed toward the base of the papilla. Sometimes, however, there is an anastomosis of the folds (Pl. 3, Fig. 13). Ehlers (p. 679) says of this species of Rhynchobolus that the cuticula of the papillae has "fine folds, which, like those of the gills, occur in spiral lines, surrounding the papilla, or more rarely, standing out as sharply projecting ridges." Concerning the gills he says (p. 676): "The chitinous covering possesses at fairly regular intervals furrows which pass around the circumference spirally; their significance probably consists in their laying the gill into definite folds when it collapses and withdraws into

the parapodial pouch." Whatever may be the condition in the case of the gills, the furrows of the papillae do not encircle those organs, for I have found that they exist on the posterior face of the papilla only. That the function of the furrows of the papillae is similar to that suggested by Ehlers for those of the gills, namely to determine the place of folding when the organs are retracted, may well be questioned, for there is no evidence that the papillae are ever retracted; there are no muscles to effect contraction, nor have I ever found the organs in a retracted condition.

The papillae have been studied in sections fixed in a mixture of corrosive sublimate and acetic acid and subsequently stained in Kleinenberg's haematoxylin; in sections fixed in corrosive sublimate and stained in iron haematoxylin; in preparations fixed in vom Rath's ('95, p. 282) picric-osmic-platinic chloride-acetic mixture (to which tap-water was sometimes added); and in methylen-blue preparations. The sections stained in iron haematoxylin I prepared, through the kindness of Professor Lloyd, in the laboratory of the Teachers College, Columbia University.

The living substance of the papillae appears to consist of either four or five cells, which are, to judge from the nuclei, of two kinds. Two of the nuclei (Pl. 1, Fig. 3; Pl. 3, Fig. 16, *nl. ba.*) found in the papillae are basal in position and larger than the others; the remaining two or three (*nl. ax.*) are nearer the apex of the papilla and also usually more nearly axial in position (Pl. 1, Figs. 3, 4; Pl. 2, Figs. 9*a*, 9*b*, 11; Pl. 3, Figs. 16, 17; Pl. 4, Figs. 26, 28, 30). The boundaries of the two cells to which the two basal nuclei belong cannot be made out by any process that I have employed.

In preparations made with vom Rath's mixture, the protoplasmic contents of the papilla are distinctly vacuolated. The vacuoles are also seen with nearly equal distinctness in the methylen-blue preparations, but not quite so clearly in sections stained with iron haematoxylin or with Kleinenberg's haematoxylin. The vacuoles are merely clearer, usually roundish, regions, which stand out distinctly, in contrast to the deeply stained granular or fibrous surrounding substance, and are quite variable in size, as is to be seen in Pl. 3, Figs. 18, 20; Pl. 4, Figs. 22, 25, 29. I believe that some of the more elongated vacuoles and the clusters of the more rounded ones in the region of the central nuclei (Figs. 22, 29), and perhaps a lighter coloring of the axial region of the papilla (Pl. 1, Fig. 4; Pl. 2, Fig. 11), gave rise to the following opinion expressed by Ehlers (p. 679): "There lies under the chitinous covering a thin sheet

of finely granular substance, *which in the papilla appears to surround a narrow cavity*, and there is connected with this sheet a thick layer of fibrous tissue."

Connective-tissue fibres pass from the connective tissue of the proboscis into the papillae (Pl. 1, Fig. 4; Pl. 2, Fig. 11; Pl. 3, Figs. 12, 19, 20; Pl. 4, Fig. 27); as a rule, these could not be traced more than half-way to the apex of the papilla, but sometimes the contents of the papilla, in great part or entirely, looked fibrous (Pl. 1, Fig. 4; Pl. 3, Figs. 12, 15, 19). These fibres of the papilla are, as Ehlers says, in close connection with a finely granular substance. There is a particularly dense and deeply stained layer of this finely granular substance immediately under the cuticula (Pl. 1, Figs. 3, 4; Pl. 2, Fig. 11; Pl. 3, Fig. 16; Pl. 4, Fig. 30); it surrounds not a cavity, but a central region in which there is a little granular substance and in which there are many vacuoles. At one point of the base of the papilla, where the connective tissue enters (Pl. 1, Fig. 4; Pl. 2, Fig. 11), and again at one point near the apex, apparently in the region of the sensory termination of the papilla (Pl. 4, Fig. 30*c*), there is a break in the dense layer of finely granular substance.

Of the two basal nuclei (*nl. ba.*) one is near the anterior, the other near the posterior face of the papilla (Pl. 2, Fig. 9*b*). They are spheroidal or ellipsoidal, and contain small irregularly scattered chromatin granules in large numbers; but in preparations stained in haematoxylin (Pl. 1, Fig. 3; Pl. 2, Figs. 9*b*, 11; Pl. 3, Figs. 16, 17) they appear less deeply colored than the remaining nuclei.

The more distal nuclei (*nl. ax.*) are more elongated, being ellipsoidal or spindle-shaped. They present an elliptical outline whether seen in sections perpendicular to the axis of the proboscis (Pl. 1, Figs. 3, 4; Pl. 2, Fig. 11; Pl. 4, Fig. 30*c*), in longitudinal sections of the proboscis passing through the axis of the papilla (Fig. 28), or in sections perpendicular to the axis of the papilla (Pl. 2, Fig. 9*a*; Pl. 3, Figs. 16, 17). The outline may be more or less pointed at one end, and is more nearly circular in the sections perpendicular to the axis of the papilla than in those parallel to the axis. The deeply staining granulations of the distal, or axial, nuclei are larger and not less numerous than those of the basal nuclei; and it is perhaps for this reason that the first-named nuclei appear more deeply stained than the basal ones. The granulations of the axial nuclei are also more evenly distributed. Both kinds of nuclei have a clearly defined nuclear membrane. In the preparations fixed in sublimate-acetic and stained in Kleinenberg's haema-

toxylin, I have seen a nucleolus in the basal nucleus only, and here only occasionally (Pl. 3, Fig. 16; Pl. 4, Fig. 24). Sometimes, though rarely, there are in a basal nucleus *two* larger granulations (Pl. 2, Fig. 11; Pl. 4, Fig. 30*c*), which may perhaps be entitled to rank as nucleoli. In preparations stained in iron haematoxylin and in those fixed in vom Rath's mixture the nucleolus is regularly seen with great distinctness near the centre of the basal nucleus (Pl. 2, Fig. 9*b*; Pl. 4, Fig. 26–28). The nucleolus is not infrequently surrounded by a light area.

From the different effects produced on the two kinds of nuclei by haematoxylin and by methylen blue, it is fair to conclude that the cells to which the basal nuclei belong are very different from those of the apical nuclei, and that they have nothing to do directly with the nervous system. They are evidently indifferent subcuticular cells, which probably have the same functions as the cover cells of more complicated sensory organs.

The central elongated nuclei found in haematoxylin preparations, judging from their position, evidently correspond to the two or three spindle-shaped cell bodies which appear in methylen-blue preparations.

"I have not succeeded," says Ehlers (p. 690), "in finding proof positive that there are nerves in the fibrous tissue which enters the papilla from the common subcuticular layer." What Ehlers was unable to find, I have, by the use of improved histological methods, succeeded in demonstrating with entirely satisfactory clearness. The spindle-shaped cells are evidently nerve cells of sensory function. For, on the one hand, the basal end is connected with one of the eighteen longitudinal nerves of the proboscis by a nerve fibre passing to that nerve, either directly or, through the intervention of the peripheral nerve plexus, indirectly; and on the other hand the peripheral end tapers toward the apex of the papilla, where it terminates in a sensory structure, the precise nature of which it is difficult to make out.

Each of the sensory cells of the papilla has the form of an elongated spindle tapering at its free end to a delicate fibre-like structure, and continuous at its basal end with a fibre traceable to a nerve trunk. This spindle-shaped enlargement, or cell body, lies in the axis of the papilla and about midway between its base and apex. An exception to this rule regarding the position of the cell body is seen in Figure 20 (Pl. 3), where the cell seems to have a basal position. I am, however, in doubt as to whether the sensory cells in this case are actually basal in position, or whether the appearance may not be due to an

accidental staining of parts adjacent to the nerve fibres, — a sort of extravasation, — accompanied by a failure to stain on the part of the real cell body and the more distal portions of the sensory cell. The spindle-shaped enlargement is sometimes stained uniformly, but more often the staining is irregular and blotchy; in some cases a nucleus is to be distinguished near the middle of the cell body in the widest part of the spindle, which it almost completely fills. In one case (Pl. **3**, Fig. 14) the nucleus was sharply differentiated from the cell body, which was not at all blotchy, but distinctly fibrous and sparsely granular.

From the distal end of the spindle-shaped cell body there passes off a fibre that, I believe, breaks up into a number of fibrils, each of which seems to me to end in a disc (Pl. **1**, Fig. 5; Pl. **3**, Fig. 14). In Figure 31 (Pl. **4**), the fibrils are quite clearly recognizable; in Figures 25 and 29 (Pl. **4**), though distinguishable, they are not so evident. The terminal discs (Pl. **3**, Fig. 18; Pl. **4**, Figs. 25, 29) may, it is true, be artefacts; but the frequency of their occurrence and the similarity of their appearance seem to me to be arguments against that supposition. Sometimes the blue is deposited in great amount around this bunch of fibrils (Pl. **3**, Figs. 12, 15, 18; Pl. **4**, Fig. 29), but in other cases it has failed entirely to stain the portion of the sensory cell that is distal to the spindle-shaped enlargement. On the other hand, there are cases in which the peripheral part of the distal portion of the sense cell has been differentiated by staining in haematoxylin (Pl. **2**, Fig. 11, not well brought out in the figure). In the case in which I have seen fibrils with their terminal discs most distinctly (Pl. **3**, Fig. 14), the discs at the ends of the fibrils are at the surface of the papilla outside the cuticula; in other preparations, the fibrils seem not to pass through the cuticula, but to end at its deep surface. It is probable that in most cases the cuticula has been artificially separated from the protoplasmic mass of the papilla, and that normally the fibrils pass to the surface of the papilla.

The connection of the cell body with one of the eighteen longitudinal nerves of the proboscis is often to be traced on a single thick section. The process which the cell body sends centripetally either joins a longitudinal nerve directly, or enters the peripheral nerve plexus, which in turn joins the longitudinal nerve (Pl. **2**, Fig. 10; Pl. **3**, Fig. 19). The basal end of each of the two or three cell bodies of the papilla seen in methylen-blue preparations (Pl. **3**, Figs. 12, 14, 20; Pl. **4**, Figs. 23, 25, 29) is prolonged into a slender nerve fibre. While the fibre belonging to one of the cells of a papilla bends to the left when it joins

the nerve plexus, that belonging to another cell of the same papilla may bend to the right, as is to be seen in Figures 10 (Pl. 2), 12, and 19 (Pl. 3). Occasionally the fibres twist around each other, and there is sometimes to be found an appearance which suggests anastomosis of these fibres, but focusing shows that in a great number of such cases the fibres cross without touching each other; in still other cases (Pl. 3, Figs. 12, 19) the blue staining is not confined to the fibres, and this makes the following out of the fibres more difficult.

The condition shown in Figure 15 (Pl. 3), which seems to be an exception to the rule that the basal end of each spindle-shaped cell body tapers into a nerve fibre, is probably the result of the well-known capriciousness of methylen-blue staining. In no case have I seen a nerve fibre arise from an abruptly rounded basal end of one of these sensory cells, but the cell body seems always to taper gradually into the nerve fibre. There are, however, quite a number of cases in which the inner end of the cell body does not simply taper into a single nerve fibre, but in which it is prolonged into a few processes which ultimately unite to form the fibre (Pl. 4, Figs. 23, 25).

These nerve fibres on their way to the longitudinal nerves often show at intervals those characteristic swellings, or varicosities, which have been so frequently figured in recent works on nerve fibres treated either by the methylen-blue or the Golgi methods.

Summary.

The papillae of the proboscis of Rhynchobolus are sensory organs. They are considered to be sensory on the following grounds: —

1. The papillae are well differentiated organs.

2. They are found over almost the entire surface of the everted proboscis.

3. They are elevated above the surrounding surface.

4. The cuticula which passes over each papilla is reduced to about two-thirds the thickness it has elsewhere on the proboscis.

It should be mentioned that the cuticula of the posterior face of each papilla is coarsely corrugated, but the significance of this wrinkling is unknown.

5. There are two or three spindle-shaped cells in a papilla, each of which terminates — either below the cuticula or more probably at the very apex of the papilla — in what is clearly a sensory structure, and each of these cells tapers gradually at its base into a nerve fibre. These

nerve fibres are connected either directly or indirectly — through the intervention of a peripheral nerve plexus — with the eighteen longitudinal nerves of the proboscis.

6. There are two basal nuclei that belong to cells which probably have the function of cover cells.

It remains to be said that there enter each papilla besides nerve fibres, connective-tissue fibres. These latter are found in close connection with a finely granular substance, of which there is a particularly dense and deeply staining layer immediately under the cuticula. Standing out in contrast to the deeply stained granular or fibrous surrounding substance are the clear, generally rounded vacuoles.

If there is any differentiation in function between papillae, it is not correlated with any pronounced difference in structure.

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EXPLANATION OF PLATES.

Abbreviations.

coel. Coelom, body-cavity.
cta. Cuticula.
cta. + e'th. Cuticula and epithelium.
gl. Gland.
gna. Jaw.
lmn. Lemniscus.
mu. crc. Circular muscle.
mu. lg. Longitudinal muscle.
n. crc. Circular nerve.
nl. ax. Axial nucleus.
nl. ba. Basal nucleus.
n. lg. Longitudinal nerve.
n. r. Radial nerve fibre skirting longitudinal muscle.
n. r.' Radial nerve fibre passing directly to the membrane superficial to the circular muscles.
pap. Papilla.
pi'tn. Peritoneum.
tis. co'nt. Connective tissue.

In many figures not only the papilla is shown, but also a portion of the underlying parts.

PLATE 1.

Fig. 1. Longitudinal section of the everted proboscis showing: (1) the sheath of the proboscis; (2) the bearer of the jaws and its subdivision; and (3) the lemniscus (*lmn.*), which marks the boundary between (1) and (2).

Narcotized in a mixture of sea-water and alcohol; fixed in Müller's fluid; stained with Beale's ammonia carmine. × *circa* 11.

Fig. 2. Cross section of the partially everted proboscis in the region of the four lemnisci (*lmn.*), showing, among other things, a diagrammatic representation of the papillae and the connection of their sensory cells with the circular and the longitudinal nerves, and also the nerve fibre (*n. r.'*) passing to the membrane which invests the circular muscles.

Chloroform, methylen blue, Bethe's ammonium molybdate for invertebrates. × 14.5.

Fig. 3. Papilla from a cross section of the proboscis, showing two "basal" and three "axial" cell nuclei.

Sea-water and alcohol, sublimate-acetic, Kleinenberg's haematoxylin. × 675.

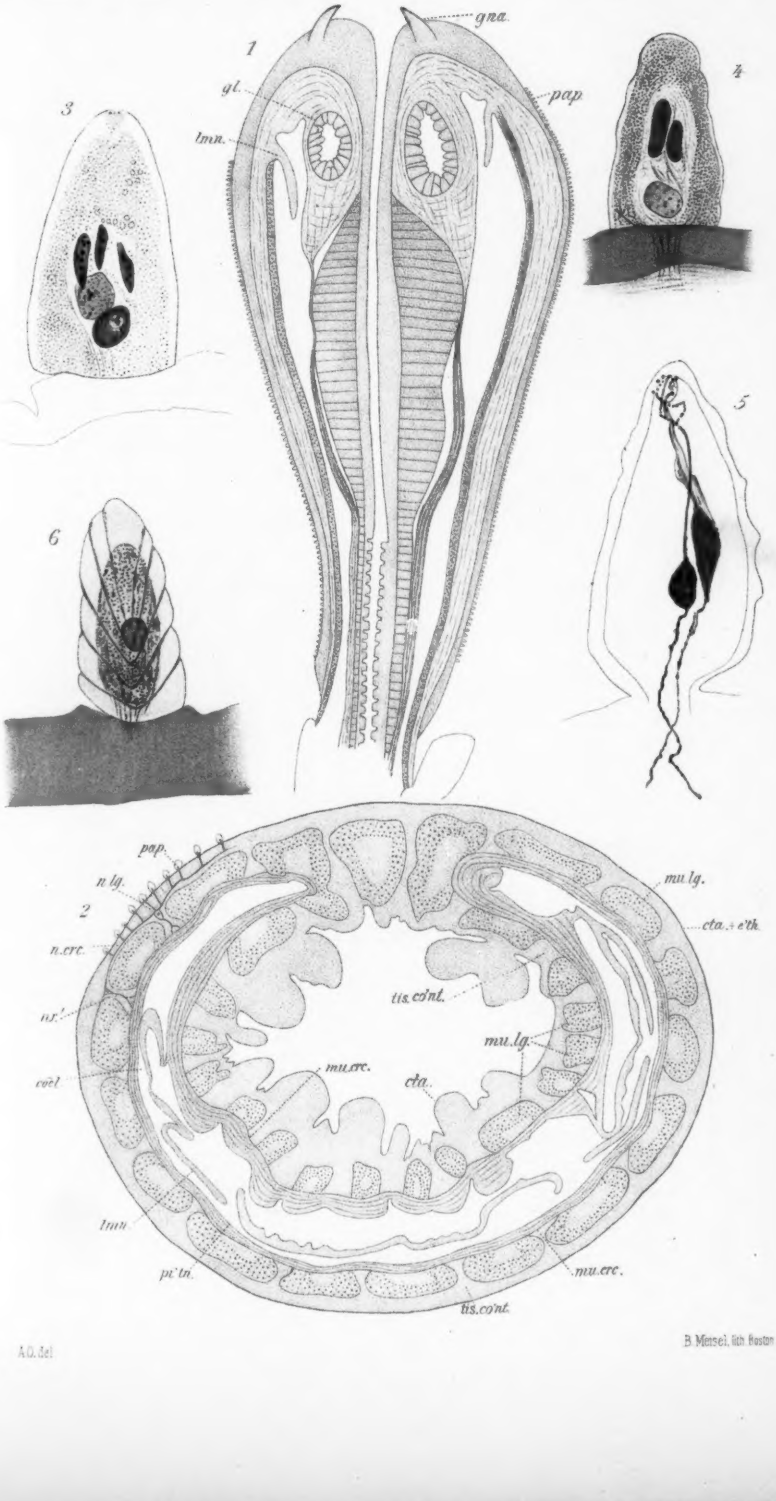
Fig. 4. Longitudinal section of a papilla, from a cross section of the proboscis, showing the two axial nuclei and one of the two basal nuclei, also fibrous structures entering the base of the papilla. Treatment the same as in Fig. 3. × 585.

Fig. 5. Longitudinal section of a papilla, from a sagittal section of the proboscis, showing two sensory axial cells with peripheral sensory termination and prolongation of the basal end of each into a slender nerve fibre.

Chloroform, methylen blue, Bethe's ammonium molybdate for invertebrates. × 650.

Fig. 6. Papilla from cross section of proboscis viewed from behind, showing the corrugations of the cuticula on the posterior face of the papilla, and in optical section the two zones of living substance together with one of the basal nuclei.

Sea-water and alcohol, sublimate-acetic, Kleinenberg's haematoxylin. × 585.



A.O. del. B. Meisel, lith. Boston

PLATE 2.

FIG. 7. Portion of cross section of proboscis, showing structure of lemniscus. Sea-water and alcohol, vom Rath's mixture. × 200.

FIG. 8. Part of Fig. 7 enlarged. × *ca.* 400.

FIGS. 9*a*, 9*b*. Sections of a papilla perpendicular to its axis. Figure 9*a* represents the more distal of the two sections, and shows the form and position of the three axial nuclei; Figure 9*b* shows the two basal nuclei. The anterior face of the papilla is directed toward the top of the plate in both cases.

Sea-water and alcohol, corrosive sublimate, iron haematoxylin.

FIG. 10. Portion of the cross section of an everted proboscis, showing one of the eighteen longitudinal nerves (*n. lg.*) cut crosswise, the peripheral nerve plexus, the union of the centripetal processes from the sense cells with the longitudinal nerve (in the case of the third papilla from the upper margin of the Figure, one of the two nerve fibres bends to the left when it enters the nerve plexus, the other to the right), a radial nerve (*n. r.*) following the surface of the longitudinal muscle (this is sketched in from an adjacent section), and another radial nerve (*n. r.'*) passing directly to the membrane which is immediately superficial to the circular muscles.

Chloroform, methylen blue, Bethe's ammonium molybdate for invertebrates. × 145.

FIG. 11. Papilla from a cross section of proboscis showing one of the basal and one of the axial nuclei; there are two large granulations in the basal nucleus.

The differentiation of the distal portion of the sense-cell is not well shown.

Sea-water and alcohol, sublimate-acetic, Kleinenberg's haematoxylin. × 460.

A.O. del. B. Meisel, lith. Boston.

PLATE 3.

FIGS. 12, 14, 15, 18, 19, 20. Preparations made by use of chloroform, methylen blue, and Bethe's ammonium molybdate for invertebrates.

FIGS. 13, 16, 17. Prepared by use of sea-water and alcohol, sublimate-acetic, Kleinenberg's haematoxylin.

FIG. 12. Papilla from cross section of proboscis, showing connective-tissue fibres passing into the papilla; deep coloration of terminal fibrils; the nerve fibres bending in opposite directions where they enter the nerve plexus. × 680.

FIG. 13. Papilla from cross section of proboscis, showing corrugations of posterior face of papilla, and the outline of one of the basal nuclei. × 460.

FIG. 14. Papilla from sagittal section of proboscis; the two sensory (axial) cells, their peripheral terminations, and their proximal nerve-fibre prolongations stained blue.

The nucleus of one of the sensory cells more deeply stained than the cell body. Cuticula distended and detached from substance of the papilla by treatment. × 710.

FIG. 15. Papilla from cross section of proboscis, showing deeply stained axial body, from which a single peripheral, deeply stained process extends to the apex of papilla, where it terminates in a specialized and stained area; the contents of the papilla in great part fibrous. × 1020.

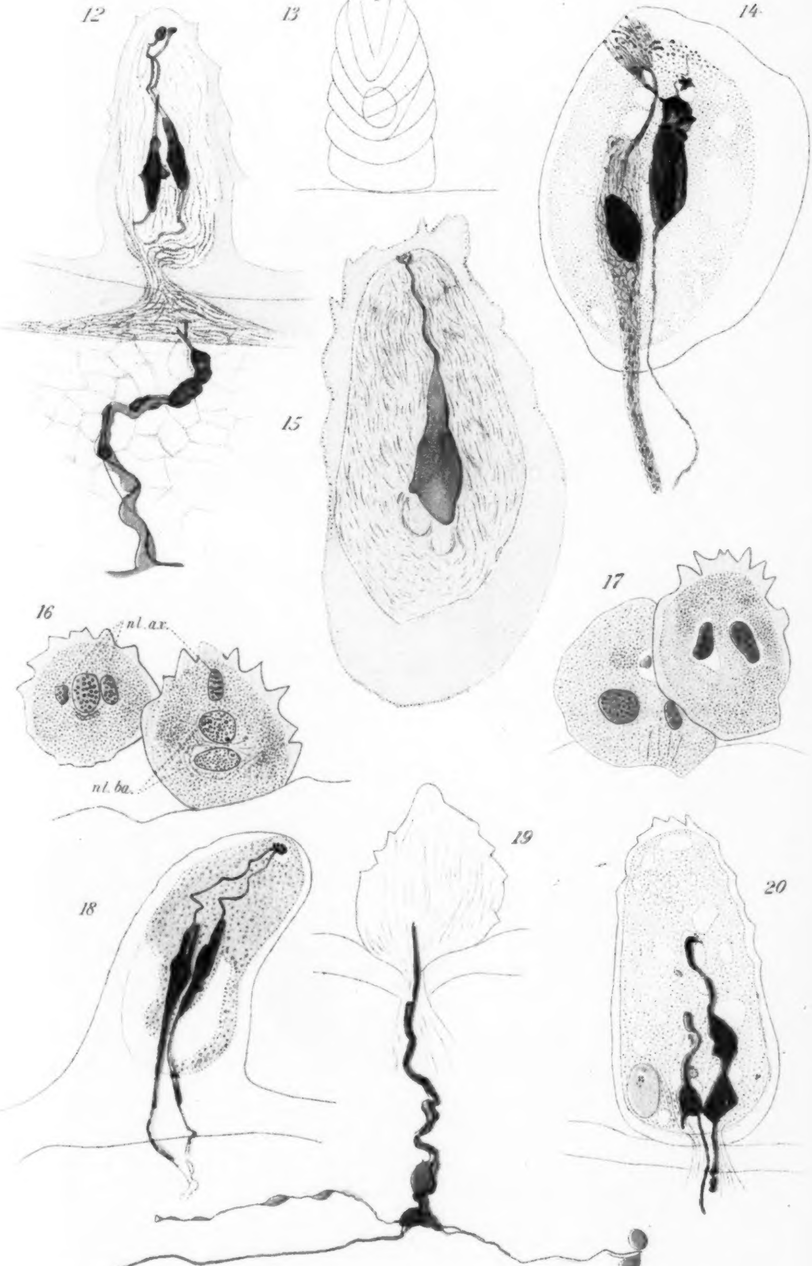
FIG. 16. Somewhat oblique cross sections of two papillae from a cross section of the proboscis. In one papilla are two basal nuclei and a part of one of the axial nuclei; in the other the three axial nuclei cut crosswise. × 670.

FIG. 17. Cross sections of two papillae from a cross section of proboscis. In one are seen two axial nuclei, each surrounded with a clear area; in the other a basal nucleus and portions of two axial (?) nuclei. × 670.

FIG. 18. Papilla from cross section of proboscis. The two sensory cells are stained throughout; their distal prolongations have a more or less spiral course and terminate in a cluster of discs at the apex of the papilla. Vacuoles large. × 715.

FIG. 19. Papilla from cross section of proboscis, showing that where the centripetal fibres from two sensory cells meet the nerve plexus, one bends to the right, the other to the left. × 725.

FIG. 20. Papilla from cross section of proboscis, showing the basal position of the sensory cell body (?); the basal end of each sensory cell is prolonged into a slender nerve fibre. × 682.5.



A.O. del.

B. Meisel, lith. Boston.

PLATE 4.

FIGS. 21–23, 25, 27, 29, 30. Longitudinal sections of papillae from cross sections of proboscis.

FIGS. 21–23, 25, 29. Preparations made by use of chloroform, methylen blue, Bethe's ammonium molybdate for invertebrates.

FIGS. 24, 30. Preparations made by use of sea-water and alcohol, sublimate-acetic, Kleinenberg's haematoxylin.

FIG. 21. Three sensory cells, two showing peripheral fibres and terminations. × 715.

FIG. 22. Papilla showing a row of axial vacuoles.
Sea-water and alcohol, Müller's fluid, Beale's ammonia carmine.

FIG. 23. The nuclei of the two sensory cells distinguishable from the cell body by their deeper stain. Peripheral and proximal fibres stained. × 710.

FIG. 24. Basal nucleus of a papilla showing a large single nucleolus. × 670.

FIG. 25. Highly vacuolated papilla, fibrils and discs of the sensory termination stained blue, the deep ends of each of the sensory cells prolonged into a few processes, which unite to form the single nerve fibre. × 700.

FIG. 26. Cross section of a small papilla, showing a nucleolus in each basal nucleus.
Sea-water and alcohol, vom Rath's mixture. × 680.

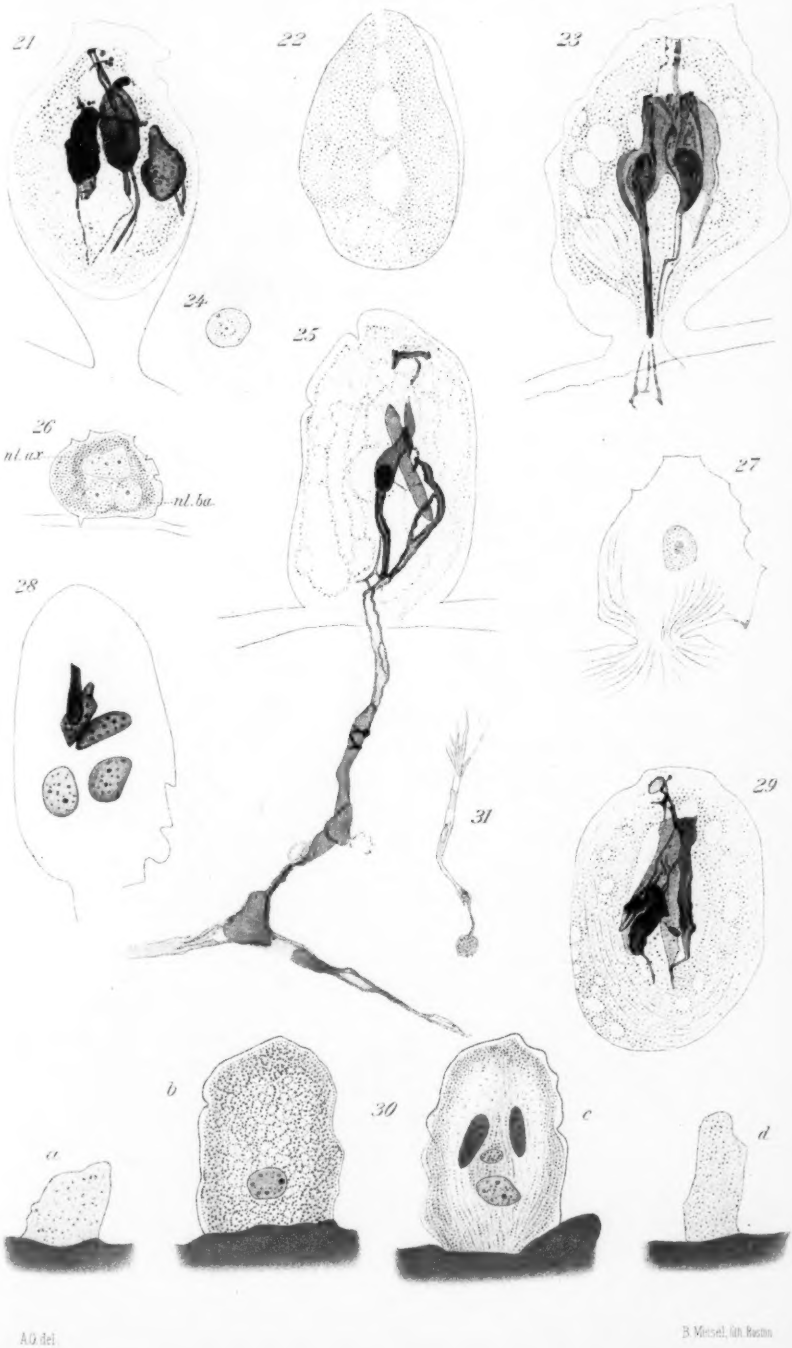
FIG. 27. Papilla showing one of the basal nuclei with large nucleolus, and the passage of connective-tissue fibrils into the papilla.
Sea-water and alcohol, vom Rath's mixture.

FIG. 28. Papilla from sagittal section of proboscis, showing three axial nuclei and two basal nuclei.
Sea-water and alcohol, sublimate, iron haematoxylin.

FIG. 29. Papilla from cross section of proboscis, showing numerous small vacuoles, fibrils and discs of sensory termination. The basal end of each sensory cell is prolonged into a slender nerve fibre. × 730.

FIGS. 30*a*–30*d*. Four successive sections from a single papilla.
FIG. 30*b* shows one of the basal nuclei; Fig. 30*c*, the other basal nucleus and the two axial nuclei.
In the region of the apex of the papilla, there is an interruption in the cortical layer of finely granular substance, not well shown, and the region is traversed by fine fibres. × 585.

FIG. 31. Fibrils from the peripheral termination of a sensory cell.



A.O. del.

B. Meisel, lith. Boston.

PLATE 5.

Fig. 32. From a photograph of the cuticula of the proboscis stripped by maceration (consult text, p. 555) and mounted on glass slide. The part of the figure nearest the top of the plate is toward the anterior end of the everted proboscis. To show the arrangement of the papillae in transverse rows. × 22.5.

Fig. 33. From a photograph of a preparation similar to that of Fig. 32, showing the appearance of the cuticula and attached papillae near the posterior end of the everted proboscis. Nine of the eighteen longitudinal columns of papillae are shown. × 18 5.

32

33

PLATE 6.

FIG. 34. Highly magnified view of portions of four transverse rows of papillae, to show the corrugations of the flattened and dried papillae, and the circular wall and pit of the cuticula at the apex of the papilla, marking the position of the termination of the sensory cells. $\times$ 110.

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